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SEAMLESS KNITWEAR - THE DESIGN SKILLS GAP

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KEYWORDS: knitwear, design, seamless, education, skills

3 *D seamless knitwear machinery allows the creation of virtually finished garments, which require little to no make-up. The introduction of this technology forces a conceptual shift in the way knitted garments are both designed and created. Moreover, it challenges educators to re-evaluate the curriculum for textile or fashion design courses.*

This study is based upon a survey of UK Higher Education Institutions, which are currently teaching knitwear design within their curricula. It discusses what is currently being taught with regards to seamless knitwear design and compares this with the views of a number of industrialists. It finally offers some suggestions as to how to teach seamless concepts.

BACKGROUND

Ten years ago, a new generation of knitting machinery was launched, heralded as 'The Future of Knitting ... Available Today' (<http://www.shimaseiki.co.jp/wholegarmente.html>). This flatbed 3D seamless knitting machinery allows the creation of virtually finished garments that require little make-up. The garments are designed so that they fall off the machine complete, with integrally knitted sleeves, side seams, details and edgings (Shima and Masui, 2002). The process of creating seamless upper body garments is based on the knitting of three tubes (body and two sleeves) which are joined at the underarm to form one tube at the shoulder, and decreased in width until the garment is bound off at the neckline (Figure 1). Often narrowing is used 'to create a raglan or circular yoke, finishing usually with a funnel

collar which is automatically cast off on the machines (Black, 2002, p178). The introduction of this technology presents significant advantages for the manufacturer, and unique challenges for the designer.

Although integral machine knitting techniques originated in the 1950s spearheaded by Macqueen's revolutionary knitting concepts (*Hosiery Trade Journal*, 1961), it was the invention of the presser foot by Betts and Robinson in the 1970s and subsequent developments in the early 1980s that allowed new construction methods, which minimized cutting waste, to be carried out by machine (Betts and Robinson 1979). Production rates were made further efficient by the introduction of holding down sinkers, controlling the knitted loops, in a new generation of Stoll 'Compact' machines, comprising specialized technology for

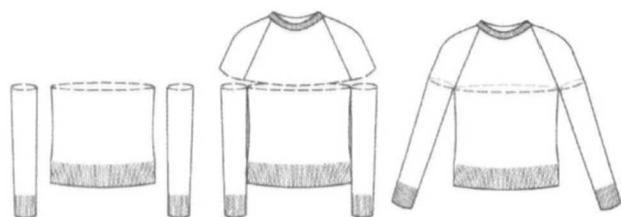
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Figure 1. Diagram demonstrating seamless knitwear construction. Three knitted tubes are created (1), which are then brought close together and joined at the underarm (2). The shoulders and chest are then knitted as one tube and finished off at the neckline to create a complete garment (3).



Figure 2. Seamless knitted jumper on a Stoll-knit and wear[®] machine.

knitting shaped panels. The use of stepper motors and precision electronic control heralded an unprecedented flexibility in machine programming, ensuring effective 3D construction (Raz, 1991).

The proponents of this technology claim it yields higher productivity and gives increased efficiency, whilst lowering both labour and materials costs (<http://www.shimaseiki.co.jp/wholegarmente.html>). The two major machine manufacturers Shima Seiki and Stoll GmbH have both created their own versions of this technology, named 'WHOLEGARMENT[®]' and 'Stoll-knit and wear[®]' respectively. Stoll claim that their 3D seamless machine can reduce production time by 60 per cent, due to reductions in checking for panel faults and time spent on garment make-up, and a 20 per cent saving in yarn costs due to the reduction in waste material (Simeoni, 2000). The uptake of this technology is slowly increasing across the globe; Shima Seiki Mfg. Ltd in Japan have stated that

they have 'manufactured around 3,500 'WHOLEGARMENT[®]' machines of which approximately 1,000 have been sold in Japan' (Hunter, 2004, p20). Hunter contends that approximately 900 'WHOLEGARMENT[®]' machines have been sold in Italy, and is confident that Stoll GmbH has also sold significant numbers of its 'knit and wear[®]' machinery (Hunter, 2004). Current manufacturing output from these machines in terms of design is mixed; examples of high-end design-focused products are still fairly sparse, with the majority of products being simple, single-colour garments, exploiting the economic advantages offered by the technology.

The exact size of the UK knitwear market is hard to quantify as knitted dresses, skirts and tops are not counted in terms of their fabric content, rather their garment style. However Mintel reports suggest that of the £37 billion UK clothing industry in 2004, knitwear would account for approximately 5 to 7 per cent (Mintel, 2005a, 2005b, 2000). The Office for National Statistics state that in 2004 the total UK manufacturers' sales of pullovers, cardigans and similar items equalled £219,492,000 (Office for National Statistics, 2005). Even though this figure has been reducing year on year, the new opportunities offered by seamless garment technology could still have significant effects on the UK industry. The apparel, footwear and textiles manufacturing sector in the UK is dominated by small and medium-sized employers (SMEs). According to Skillfast UK, the Sector Skills Council for apparel, footwear, textiles and related businesses, more than 80 per cent of establishments have 10 employees or less with only 1 per cent with over 200 (Skillfast UK, 2005). Anecdotally, a recent European Regional Development Fund (ERDF)-funded project which took place at The University of Manchester (findings as yet unpublished) found that knitwear manufacturers in the North West of England employed on average 12 workers. Seamless

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technology could therefore be advantageous to the UK manufacturing market as it is more machine rather than labour intensive, and enables quality products to be manufactured with reduced production times and thus labour costs.

The introduction of this complex technology forces a conceptual shift in the way knitted garments are designed and created. Traditional knitwear design is based around tailoring with pattern blocks cut from knitted panels (known as cut and sew), or flat panels knitted to predefined shapes (known as shaping or fully fashioning), which are assembled in the make-up process (Figures 3 and 4). Although hand pin seamless knitting can be dated back to before 1400AD (Spencer, 2001), 3D seamless machine knitting presents a new way of making clothing, forcing the designer to reassess ancient hand techniques. Moreover, technical advances in knitting have 'outstripped the market's ability to absorb and utilize it and the customer has to be educated to recognize the benefits' (Black, 2002, p120). The customer in this case can refer to both the retailer who needs to appreciate the marketable qualities of seamless garments, and the consumer who needs to recognize the ergonomic advantages of wearing garments without bulky seams. For this to happen, garments should be introduced to the market which do not simply mirror traditional fully fashioned shapes, but offer new styles which could only successfully be achieved through seamless construction.

In order to assess the operability of the 'technical advances' mentioned by Black, a study is being carried out to compare and evaluate the CAD systems used for 3D seamless design from a designer's point of view (Black and Powell, 2005). As all seamless garment designs must be created through the CAD/CAM systems associated with the machines, for example the Shima Seiki SDS®-ONE system and the Stoll M1 workstation, it is important that designers understand and appreciate the potential and constraints

of these technologies. Millington points out that if the revolution in 3D seamless knitwear is to bear the most productive fruit, then educational and training facilities are imperative (Millington, 2000).

This paradigm shift also challenges educators to re-evaluate the curriculum for textile or fashion design courses. Knitwear design is taught within many textiles and fashion degree programmes in the UK with students learning to create knitted structures using hand-flat V-bed or domestic machinery, along with the principles of garment creation through cut and sew or shaping technology. Alongside learning such concepts students must be able to appreciate fabric handle and drape, understand the importance of yarn count and fibre choice, and be able to use their aesthetic judgement sympathetically to combine attractive colours and patterns. They must learn drawing and design development skills, alongside a wide range of other topics such as costing and economics, CAD, textile

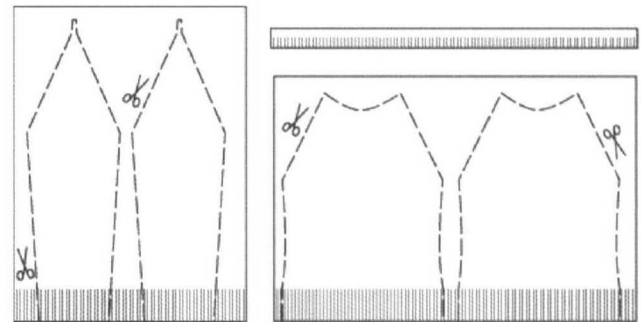


Figure 3. Diagram showing panels knitted for cut and sew construction.

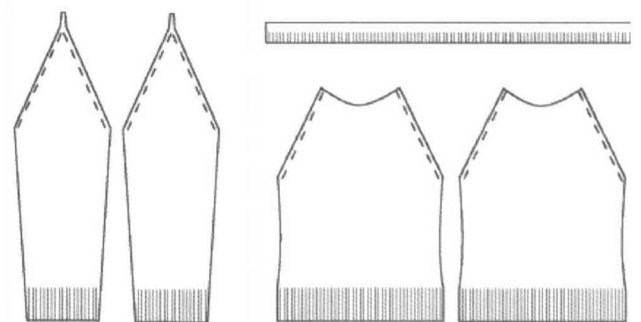


Figure 4. Diagram showing garment pieces knitted to shape for fully fashioned construction.

materials, pattern-cutting, knitting, weaving and printing technology. With the advent of this 'new era in modern knitting' (<http://www.shimaseiki.co.jp/wholegarmente.html>), a number of questions are raised: How do UK higher education institutions deal with teaching this new technology? Are the principles and practice of seamless knitwear design being taught at all? Is there indeed time within already crowded curricula to teach this new technology? Do graduating designers have the skills that industry needs? Moreover, as posed by Wayman, should educators be reactive to the ever-changing needs of industry: by the time programme curricula are altered to suit industry's expectations, graduates may possess outdated skills (Wayman, 2000).

THE NEW ROLE OF THE DESIGNER

As Perks, Cooper and Jones outline, the role of the designer has evolved substantially. Design in the new product development process is varied, with designers sometimes becoming involved in areas as diverse as marketing, manufacturing, product launches, and sales support (Perks *et al*, 2005). A study by Roodhouse which looked at the designer fashion manufacturing industry in the North-West, Yorkshire and Humber regions of England identified that most companies employed less than five full-time employees, and that although design was a major job role, administrative, management and sales functions were significant (Roodhouse, 2003). With such small employee numbers it is evident that designers need to learn broader business skills in order to improve their businesses. This notion is supported by Skillfast UK, who state that qualifications and training for employees of this industry should include subjects such as IT and business administration. They also state that employers have misgivings about the skills that higher education graduates

are currently able to bring to their companies, as they feel many courses lack the depth of development in technical competency required to enable companies to compete in such a global market (Skillfast UK, 2005). They suggest that these additional skills be delivered through vocational qualifications and foundation degrees, and that more flexible learning strategies be implemented as the competitive nature of working in global markets means that a majority of companies are unable to release employees for long periods of training.

A study by Yang *et al* looked at the competencies required for industrial design (ID) graduates entering employment (Yang *et al*, 2005). Similar to fashion and textile design students, industrial design students are recruited from diverse backgrounds so their abilities and expectations can vary considerably. As well as the design-based courses, ID students take a number of different modules ranging from engineering to management and computer-related courses. They must have cognitive abilities (including critical and creative thinking, problem-solving, oral and graphic communication skills), specific skills such as modelmaking, social context competency (including teamwork, entrepreneurship and grasp of cultural heritage) as well as subject matter expertise (Yang *et al*, 2005). There subsequently exists a wide range of teaching needs for universities and colleges to cover in order to suitably equip students for employment. Yang suggests that design education needs to be reviewed and updated in order to keep abreast of technological advances, and that no matter whether design students are educated as generalists or specialists, they must be encouraged to become lifelong learners and reflective practitioners in order to adapt to future challenges (Yang *et al*, 2005). This is relevant across design education in general, and suggests that new technologies such as 3D seamless knitwear design must

be tackled in some way in order to introduce the concept to designers, who may then specialize in such an area when in employment.

Traditional knitwear design involves the creation of a technically complex product according to aesthetic considerations (Eckert, 1999). It combines fashion and textile design: garment silhouettes are designed at the same time as the fabric. In terms of production, knitwear design can be very different depending on target customer and market. For some designers it involves re-colouring standard pattern blocks, or changing silhouettes marginally to reflect subtle changes in the style of basic garments. For other designers it can mean creating radical new shapes and introducing innovative new fabric structures.

Since the recession in the 1990s, the UK textile industry has been hit hard, facing immense competition from low labour cost countries. 3D seamless knitwear technology reduces labour time by creating garments that are virtually complete, drastically reducing labour-intensive making-up. It offers opportunities for the knitwear industry to overcome labour cost differentials and capitalize on the UK's renowned design heritage. Alongside this technology shift, the role of the designer must also change; an ability to understand 3D design concepts and the machine parameters is required to complement traditional skills. Moreover, an ability to communicate effectively with technical colleagues is essential. Eckert states that knitted structures are inherently difficult to communicate, and these communication problems are exacerbated by the differences between designers and technicians 'who have different cognitive styles and very little overlapping expertise' (Eckert, 1999, p29).

Eckert and Stacey recognize that sources of inspiration for knitwear designers include other knitted garments, other

types of design (e.g. other types of textiles), works of art and images or phenomena from nature and everyday life (Eckert and Stacey, 2000). Decisions are based on the designer's fashion research, which considers the target customer and available resources (Eckert and Demaid, 1997). Eckert and Demaid studied the knitwear design process in industry, and found that approximately 30 per cent of designs specified were not suitable for production. Their research shows that designers often settled for suggestions presented by technicians, which sometimes bore little resemblance to the original design (Eckert and Demaid, 1997). Designers are influenced by many sources when



Figure 5. Seamless garment demonstrating lack of side seam, and accurate matching of stripes.



Figure 6. Seamless garment turned inside out to show the joining of the body and sleeve tubes at the underarm. This process omits uncomfortable underarm seams.

creating their ideas, whereas technicians' main objectives are to produce garments easily and quickly. Skillfast report that redundancy and early retirement is reducing the number of technical staff in the clothing industry, and this is being compounded by the student appetite for fashion/design-related degree courses in higher education (Skillfast UK, 2005). As a smaller pool of technical staff become more in demand, one remedy could be to give the growing number of designers a stronger technical grounding. Yet Eckert and Demaid noted hostility to the idea of technical training from both designers themselves and senior management, fearing the designers' creativity may be reduced by knowledge of the technical limitations (Eckert and Demaid, 1997).

3D design poses more technical restraints than traditional manufacturing, and this has been acknowledged by machine manufacturers: over recent years Shima Seiki have placed emphasis on making their technology easier to use. They are focusing on design at their Wakayama base, and are currently producing 2500 new 'WHOLEGARMENT®' designs a year, which can be adapted by manufacturers (*Knitting International*, 2005). Manufacturers are also able to download 'knit and wear®' patterns from Stoll's website (<http://www.stollpattern.com>). Yet it must be queried as to whether this is the right path to follow. Do we really want our clothes to be designed by machine manufacturers? If so, then designing 3D seamless garments could become nothing more than a process of mix and match with predefined garment modules (type of neckline, sleeve shape, etc). Could this even be called design? Although this method may help overcome problems caused by the lack of technical understanding by designers, this jigsaw approach to creating garments could, in fact, exacerbate the technology skills gap between the designers and the potential of the machinery.

RESEARCH OBJECTIVES AND METHODOLOGY

The Design research group within the School of Materials, University of Manchester, UK, decided to explore the extent to which UK Higher Education Institutes (HEIs) were embracing this new knitting technology, and aimed to discover what skills textile and fashion academics thought were key for knitwear designers. To set this into context, a number of manufacturers were consulted.

A countrywide survey was carried out of UK HEIs, through email, post and telephone. Both open and closed questions were used to provide both qualitative and quantitative data for analysis. Four knitwear manufacturers were contacted and case studies compiled detailing their experiences of 3D seamless knitting. Through this multiple method technique (Easterby-Smith, Thorpe and Lowe, 2002), a coherent picture of the current skills gap relating to 3D seamless knitting could be compiled, and remedial solutions suggested.

According to statistics published by HESA (the central resource for Higher Education statistics), in 2003/4 there were 109,955 full-time undergraduate students registered on creative arts and design programmes in the UK (<http://www.hesa.ac.uk/holisdocs/pubinfo/student/subject0304.htm>). A study by the 'think tank' group DEMOS has revealed that students applying for design courses in 2006/7 will have a choice of 2,167 HE courses (Design Skills Advisory Panel, 2005). There are 67 UK HEIs registered through UCAS as having textile or fashion undergraduate degree programmes (wwwucas.ac.uk), therefore assuming a class size of approximately 40, it can be estimated that at least 2,680 new designers graduate each year, with the potential of becoming knitwear designers. A study by Pearson *et al* in 2000 found that there were approximately 1,500 textile designers graduating each year, but only 1,510 textile designers employed in the UK. Unless a 100 per cent

turnover per year of textile designers in work exists, the majority of graduates would not be able to gain employment as designers in the UK (Pearson *et al*, 2000).

Each of the 67 UCAS registered institutions were contacted, alongside the Royal College of Art, which offers a postgraduate programme in knitwear. Preliminary contact was made to identify the departmental expert for knitwear within each institution. This process ascertained that six institutes did not teach knit within their textile or fashion programmes. A further 19 institutions did not reply, indicating perhaps that they also did not teach knit. Academics at the remaining 43 institutions were asked to complete a simple questionnaire about what was taught at their institutions and their opinions on how to teach 3D seamless knitwear design.

THE QUESTIONNAIRE

Twenty-six out the 43 institutions completed and emailed or sent back hard copies of the questionnaire. The universities and colleges that took part are listed in Table 1.

The first question asked whether the courses included a knit component. Twenty-two out of the 26 institutions answered 'yes' to this question. It was also indicated at this stage that two of these colleges did not cover knit at degree level, instead providing BTEC or OCN/NOCN qualifications. The four colleges who did not cover elements of knitting were subsequently eliminated from all further questions (City College Coventry, New College Nottingham, University of Portsmouth, Southampton Institute).

The further questions were posed to the remaining 22 institutions.

Question two asked whether seamless knitwear design was taught within each individual textile and fashion programme. The results showed that only 8 out of 22 institutions covered any element of 3D seamless garment

design (36 per cent), with nearly twice as many not referring to the emerging subject within their curriculum.

The depth to which 3D seamless knitting was taught by those eight universities was fairly perfunctory with generally only basic principles and technology being covered. Only the University of Manchester demonstrated this technology in a laboratory session. The reason for this is suggested by the results of question six, which asks whether the universities had access to 3D seamless garment machinery: 4 out of 22 answered 'yes' (18 per cent), and out of these institutions, only the University of Manchester had access to machinery in-house.

The machinery available in-house within the institutions surveyed can be segmented into five categories: domestic machinery, Dubied V-bed machinery, electronic flat-bed knitting machinery, 3D seamless machinery and other machinery. Figure 7 demonstrates that 21 out of 22 universities had Dubied V-bed machines, with just over half the number of institutions possessing any electronic flat-bed knitting machinery.

The level of competence gained by students at institutions with electronic flat-bed knitting machinery was varied. On some programmes the students did not

Higher Education Institutions which took part in the survey	
Bath Spa University College	Royal College of Art
Brighton University	Southampton Institute
Central Saint Martins	The University of Bolton
City College Coventry	The University of Manchester
De Montfort University	University of Central England
Dundee University	University of Derby
Glasgow School of Art	University of Huddersfield
Kingston University	University of Leeds
London College of Fashion	University of Portsmouth
Manchester Metropolitan University	University of the West of England
New College Nottingham	University of Westminster
Northumbria University	Winchester School of Art
Nottingham Trent University	Heriot Watt University

Table 1. Higher Education Institutions which took part in the survey.

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work with the machinery, they instead used CAD software to design patterns for the machines, which may have resulted in them being distanced from the technology. In most cases only trained technical staff were able to run the machinery, whilst students used networked CAD systems. A few students were able to perform basic machine processes (start/stop the machine etc), therefore becoming more involved in the fabric production, with some students becoming proficient. One respondent commented that depending on the student's project and ability, he/she would be free to experiment on the machinery and, given time and experience, would gain a degree of independence.

In order to design and produce seamless garments in-house, respondents were asked to rate the following as the most useful in their opinion (one=most useful, four=least useful):

- access to machinery on site
- design friendly software
- interface with technicians
- industrial contacts.

The respondents gave almost equal weighting to the importance of having access to machinery on site, of having design friendly software and of having a good interface with technical staff. However, it was generally seen of much less importance for HEIs to have good industrial contacts for the design and creation of seamless garments in-house (although a few institutions contradicted this opinion). Three institutions failed to complete this section.

Skills seen as most important for a knitwear designer today included technical skills, knowledge of yarns, a clear sense of fashion and colour, and strong design ability (Figure 8). Other key skills included creativity and knowledge of garment construction and fabric structures. The study by Pearson *et al* identified key skills for textile designers to include communication skills, with problem-

solving and team-working skills amongst other general skills (Pearson *et al*, 2000). Communication skills and patience were mentioned as key skills for a knitwear designer in this research (Figure 8), but were rated as less important than subject-specific skills.

Eighteen out of 22 universities stated that there was not enough time available within current curricula to cover seamless garment construction to a sufficient depth. Subsequently the majority of institutions believed that this subject should be taught at postgraduate level, with only 6 out of 22 stating that this was not necessary (Figure 9).

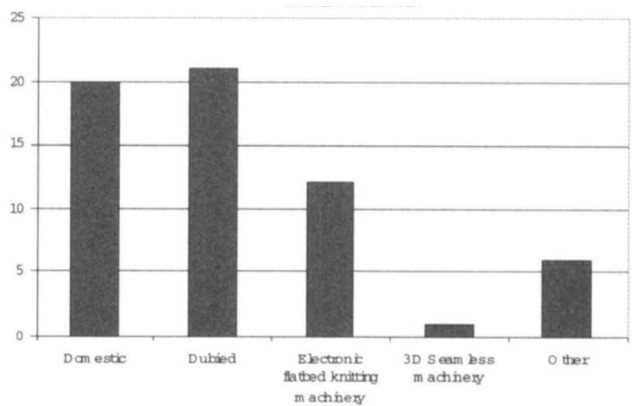


Figure 7. What knitting machinery do you have?

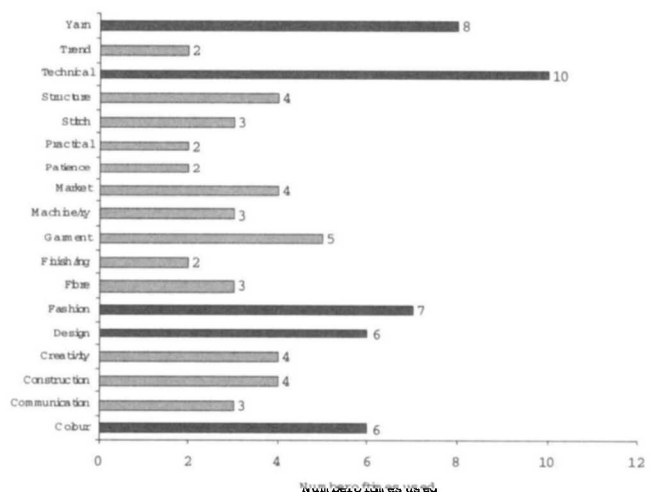


Figure 8. Chart showing common words used by respondents in describing key skills for a knitwear designer (words used by two or more HEIs).

THE INDUSTRY VIEW

To set these academic findings into context, four case studies of international knitwear companies with knowledge or experience of seamless garment production were undertaken. The companies (which have been kept anonymous) were contacted and asked their views about seamless knitwear, and whether they felt a gap was appearing between the potential of the technology and the skills of graduating designers.

COMPANY ONE CASE STUDY

Company One is based in central England and possesses one of the largest collections of 3D seamless garment knitting machines in the world. Their 80 Shima Seiki SWG-X 'WHOLEGARMENT®' machines produce seamless products which can be garment dyed at a sister company, allowing a very quick route to market. In recent years the company has transformed from a volume supplier to a highly responsive and flexible operation, servicing the quick response requirements of UK high street and middle market retailers.

The spokesperson, one of three knitwear designers at Company One, stated that their seamless garments are usually based on traditional seamed garments, as they are supplying to the high street. Obstacles to producing

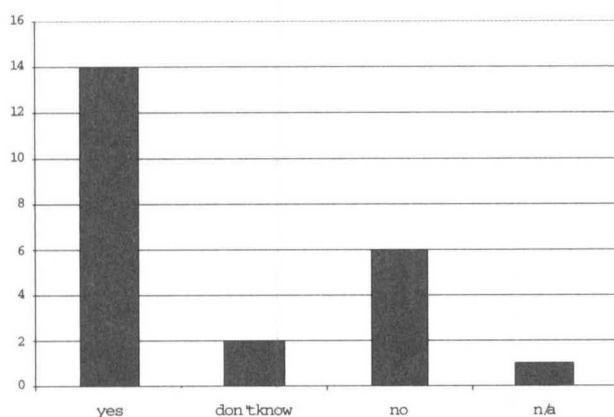


Figure 9. Does seamless knitwear design warrant a separate postgraduate programme?

innovative seamless styles include the programming time, which can be lengthy. Additionally, in order to be cost effective, each garment must knit in under 60 minutes, which currently makes some styles unfeasible. This designer did not believe that there was a design skills gap with recently graduated designers in relation to creating seamless knitwear, but stated that essential skills for a graduate to design viable seamless garments included a sound knowledge of knitted structures and techniques, good awareness of fashion trends and knowledge of yarns.

COMPANY TWO CASE STUDY

Company Two was founded in the 1800s and is one of Scotland's leading cashmere specialists. Alongside traditional fully-fashioned cashmere production, Company Two has introduced 'WHOLEGARMENT®' technology in twelve and eight gauge. Their cashmere garments are sold internationally at the high end of the fashion market. They are currently converting traditional knitwear shapes into seamless pieces, rather than designing new shapes that wrap around the body.

The managing director of Company Two believes that there is a significant gap between education and industry with regard to creating seamless garments. They do not employ knitwear designers because they feel that designers do not understand sufficiently how machines function and are programmed. Instead they employ individuals who specify garments and can convert garment sketches into the appropriate knit language. This MD sees a visible skills gap between the programmers and the potential of the machinery and feels that after four to five years, their technicians are still struggling to get to grips with this technology. Company Two stated that any postgraduate programme teaching seamless knitwear design must contain a strong garment programming element.

COMPANY THREE CASE STUDY

Company Three is based in Switzerland, and produces knitwear for a designer label, selling into 102 countries with more than 5,000 points of sale. The knitwear collection development department at Company Three employs 18 staff, including knitwear developers, technologist and CAD operators.

The head of collection development for knitwear stated that they produce seamless garments using 'Stoll-knit and wear®' technology, but this currently only accounts for 1 per cent of all deliveries. The biggest obstacle faced by Company Three in producing seamless garments is that of cost: the high street consumer does not yet see the benefit of seamless garments, and is therefore unwilling to accept higher prices.

Company Three employs designers but, as they do not have any recent graduates, they cannot identify a design skills gap relating to designing seamless knitwear. However, they do believe that graduates need to have a more in depth understanding of basic knitting technology before they can progress to designing seamless garments.

COMPANY FOUR CASE STUDY

Company Four, which has manufacturing bases in Hong Kong and China, specializes in seamless apparel. As well as using Santoni circular technology for knitting seamfree underwear, they use 'Stoll-knit and wear®' technology for producing seamless outerwear. They are currently producing for the domestic market in China.

Their spokesperson stated that they produce seamless garments both from traditional fully-fashioned pattern blocks and from new ideas, designed around the body. They employ two knitwear designers and have a number of Stoll machine technicians. It was felt that purely creative designers are not able to master the seamless technology;

knitting technology must be fully understood alongside a comprehensive understanding of machine functions before any seamless designing can commence. With this in mind, the spokesperson concluded that there is definitely a design skills gap between the knowledge held by recent design graduates in relation to designing seamless knitwear and the potential of the technology, and in fact it is very difficult to train a seamless knitwear designer. It would be beneficial for students to have knowledge of garment programming including complicated manual commands as well as automatic blocks.

The spokesperson stated that obstacles to designing innovative seamless knitwear for Company Four include the limitations of the machine and its software. Sizing or alteration of pattern or style is difficult, because this often requires programmes to be started again from the beginning. This is therefore a barrier to producing economically viable commercial garments, making seamless fashion more suitable for the high-end European market.

DISCUSSION

This research aimed to clarify how HEIs were teaching the processes of 3D seamless knitwear design and in fact whether the principles and practice of this technology were being taught at all. Data from this research clearly shows that UK Higher Education as a whole is failing to address these complicated developments; the process of 3D seamless knitwear design is taught very infrequently in higher across UK HEIs, and when it is taught it is only to a very limited degree. Most institutions have no access to 3D seamless garment machinery, with only half having access to any electronic flat-bed knitting machinery.

This research also asked whether graduating designers have the skills needed by the knitwear industry and consequently whether a skills gap was evident. Contrary

to prior assumptions by the research team, the companies contacted had fairly neutral views. Only Company Four noted a clear skills gap, stating that it is very difficult to train a seamless designer. Company Two did not employ purely creative designers because they felt that they would not understand the machinery to a sufficient degree. For industry to criticise the skills of graduating designers would, in some cases, be to criticise their own employees, therefore a fairly neutral response may be expected. Yet with the majority of UK HEIs failing to teach these concepts at all within current undergraduate curricula, and with the programming of such machines being so complex, it is clear that a gap must exist which should be addressed by educators. With reference to Wayman, it is believed in this case that educators should be reactive to needs of industry, since if no changes are made the gap may become too large to bridge.

In order for students to start designing 3D seamless garments, the general academic view was that access to machinery, designer-friendly software and a strong interface with technical staff was equally important. Additionally, the most common key skill identified by academics as paramount for a knitwear designer was a significant technical knowledge. In contrast to Eckert and Demaid's findings (1997), the academic view was that technical knowledge would not stifle design creativity; on the contrary it was felt to be essential for designing 3D knitwear. Moreover, the lack of technical know-how is the reason why Company Two did not employ creative designers at all. Company Four stated that a full understanding of the machine technology is vital before seamless designing can begin. Company Three concurred, stating that graduates need to have an in-depth knowledge of knitting technology. If designers graduated with a greater technical knowledge, the number of impractical design solutions offered should

be lower and communication barriers between technologists and designers should lift. The data from this research indicates that an emphasis should be given to knitwear technology within HEI textile and fashion programmes if students are to successfully progress to seamless design.

Company Two stated that their technicians are still coming to terms with this complex technology. If design students had access to seamless machinery and closer communication with technical staff, it is possible that these two groups, described as being both cognitively and culturally different, could use their differences to overcome technical barriers in a positive way.

It was generally felt that a postgraduate programme to study 3D seamless knitwear design would help overcome the skills gap between education and industry. Such a postgraduate programme would have to be technically focused and should include a strong element of machine programming, as indicated by Companies Two and Four, as well as more yarn and fibre appreciation, which is essential when choosing suitable raw materials which will knit effectively and still give an attractive finish. If students understood how to design basic 3D seamless garments within a postgraduate programme, they should be able to progress to designing more novel yet commercially viable forms when in industry. Moreover, if seamless garment production evolved in terms of design, bringing fresh and innovative garment shapes onto the market, then high street customers may see the benefits of seamless technology, and garments could command a higher market price.

Research currently being carried out by the University of Manchester and Manchester Metropolitan University focuses on how to teach basic seamless concepts to undergraduate design students using a Problem Based Learning (PBL) approach. Ongoing research by Sayer and Shaw is based around the use of Dubied hand flat V-bed

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machinery, with students given briefs to design and produce 3D seamless products by hand on the machinery. The research documented in this paper has discovered that Dubied hand flat V-bed machinery is widely used in HEIs, therefore opening up the possibility of this PBL model being rolled out nationwide. The basic 3D seamless concepts learnt through this method would subsequently prepare students for the postgraduate programme mentioned above.

It is clear that the creative promise of 3D seamless garment technology is yet to be fully exploited, with manufacturers concerned primarily with cost benefits. This design potential needs to be addressed by both educators and designers alike, before the gap between designers' knowledge and the potential of the machinery becomes too wide to bridge.

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